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Green manure coupled with SRI method for sustainable yield and soil health

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Abstract
The agriculture of the modern chemical era concentrates on maximum output but overlooks input efficiency as a result of which it has not been sustainable. The estimation of achievable yield through adoption of improved rice varieties reveals wide yield gaps, the major factor responsible for such gap is low soil fertility. Green manuring of rice is a well-established practice and saving of fertilizer N through green manuring ranged from 30 to 100 kg N ha-1Nitrogen–fixing systems provide an economically attractive and ecologically sound means of reducing external inputs and improving internal resources. The large scale demonstration was with an objective to sensitize the rice farmers on importance of soil health and to focus on sustainable yield through adoption of green manure (Sesbania) followed by SRI cultivation. The demonstration was done in 120 hectares covering 120 rice farmers grouped into 5 clusters. in conventional practice the average no. of panicles per meter square was only 323 whereas it was 388 in demonstration plot, similarly the average grain yield was 5138 kg/ha and 6211 kg/ha in conventional and demonstration plots respectively. The study result showed that the average drymatter production in one hectare of demonstration plot was around 2.34 t/ha and the average nitrogen fixed in the soil was found to be 50.48 kg/ha. before the intervention the average net return was only Rs.20,609 per hectare whereas it was Rs.34,199 from conventional and demonstration plots respectively similarly the average cost to benefit ratio was 1.60 in conventional method and later it was notice 1.90 in demo plot. Hence, the farmers growing rice in wetland ecosystem are advised to take-up green manure followed by SRI as cropping pattern for sustainable yield and economic returns.

Keywords: Green manure, SRI, economics

Introduction
Rice (*Oryza sativa* L.) Is the staple food of Asia and part of the Pacific? Over 90 percent of the world's rice is produced and consumed in the Asia-Pacific Region. In India, rice is grown in almost half the states, with West Bengal leading the way in terms of production with 14.71 million tonnes, followed by Uttar Pradesh (12.22 million tonnes) and Andhra Pradesh (11.57 million tonnes). In Tamil Nadu rice is only the staple cereal crop, rice growers have used a large amount of chemical fertilizer and herbicide to increase rice field's productivity. To increase agricultural production, in conventional agriculture chemical N fertilizers are often overused to such an extent that environment is adversely affected. Concentrations of several reactive oxidized and reduced forms of N such as N_2O, NO_3, NH_3 are reported to exhibit an increase in their concentrations in the environment (Fagodiya *et al.*, 2017; Meena *et al.*, 2018b) [6, 11]. The agriculture of the modern chemical era concentrates on maximum output but overlooks input efficiency as a result of which it has not been sustainable. The estimation of achievable yield through adoption of improved rice varieties reveals wide yield gaps, the major factor responsible for such gap is low soil fertility. The incorporation of plant residues into the soil is of the importance to reduce the soil application of contains plant nutrients. Green manuring with N fixing legume crops can provide a substantial quantity of rice N requirement with organic matter to wetland rice soils. Additionally, this technology is safe for human health and environmentally friendly. The soil management practices to increase fertility and productivity should include an increase in biomass along with reducing its decomposition (Bunch 2012) [3]. In Tamil Nadu, some techniques have been implemented for rice production to reduce the use of chemical fertilizer and herbicide inputs (Jeon *et al.*, 2006) [18]. One of the methodologies is Green Manure (GM) incorporation followed by SRI cultivation. Green manuring of rice is a well-established practice and saving of fertilizer N through green manuring ranged from 30 to 100 kg N ha^{-1}Nitrogen–fixing systems provide an economically attractive and ecologically sound means of reducing external inputs and improving internal

resources (Bohlool *et al.*, 1992) [2]. The use of green manure crops could lead to increase soil organic matter and nitrogen availability. The main advantages of green manures are: (1) the improvement of the physico-chemical soil properties (Jeon *et al.*, 2008) [19]; (2) the management of weeds (Hatcher and Melander, 2003) [14]; (3) the protection from nematodes (DuPont *et al.*, 2009). Therefore, the objective of the study was to demonstrate the GM with SRI in wetland ecosystem of Kancheepuram district.

Materials and Methods

The rice farmers generally grow rice crop either in sequence or sometimes adopt one season as fallow which leads to depletion of soil nutrients and in-turn disturbs the soil health. In-order to improve the soil health and productivity of rice crop, this particular intervention was demonstrated among the rice growers through “Tamil Nadu Irrigated Agriculture Modernisation Project” (TN-IAMP) in Lower Palar Sub Basin of Kancheepuram district of Tamil Nadu during 2019-20. The large scale demonstration was with an objective to sensitize the rice farmers on importance of soil health and to focus on sustainable yield through adoption of green manure (Sesbania) followed by SRI cultivation. The demonstration was done in 120 hectares covering 120 rice farmers grouped into 5 clusters (Fig. 1). In-order to have a representation of 120 field plots, in the present paper only one cluster comprising of 25 plots are discussed here. The values obtained from these 25 farmer field can be taken as representative data of 120 farmers or total population of the intervention. The parameters taken for the study were number of grains/panicle, number of Panicle/m^2, Grain Yield (kg/ha) and Percentage yield increase were assessed for conventional practice of rice production and green manure followed by SRI method of rice cultivation. The farmers were advised to grow green manure crop and were advised to practice in-situ mulching of green manure before taking-up rice transplanting. Green Manuring is the process of turning of green plants into the soil either by raising them in same field or plants grown elsewhere at the green stage before flowering and incorporated into the soil. It is a good management practice in agricultural production, because it can improve soil fertility and quality (Lee *et al.*, 2010) [10].

Fig 1: Demonstration of green manure

Results and Discussion

Yield and Biometric

It is quite widely accepted that SRI techniques promote visible changes in the growth patterns and morphology of individual rice plants, specifically a vigorous production of numerous tillers (shoots with the potential to produce grain bearing panicles). Some studies have confirmed that SRI methods produce physiological and morphological changes in rice plants that can lead to improved yields and higher factor productivity (Vijayakumar *et al.*, 2006; Thakur *et al.*, 2010). In-order to have a clear picture of results, the yield and biometric parameters were assessed for the conventional practices and demonstration performed. The details of data obtained are tabulated in the Table-1 and the pictorial form is presented in Fig. 2.

Table 1: Yield and biometrics of conventional and GM-SRI

Plot No.	Conventional			GM-SRI			Yield increase (%)
	Panicle/m^2	Grains/panicle	yield (kg/ha)	Panicle/m^2	Grains/panicle	yield (kg/ha)	
1	318	92	5480	369	106	6290	14.78
2	327	90	5100	398	113	6300	23.53
3	320	96	5075	400	108	6180	21.77
4	326	91	5600	412	116	6300	12.50
5	318	95	5056	401	109	6108	20.81
6	323	92	5065	395	111	6209	22.59
7	316	93	5200	368	117	6250	20.19
8	330	97	5180	370	106	6274	21.12
9	326	94	5142	386	111	6150	19.60
10	329	96	5136	384	108	6098	18.73
11	319	91	5084	390	115	6140	20.77
12	329	95	5115	395	110	6135	19.94
13	316	92	5150	391	108	6102	18.49
14	320	93	5146	397	112	6230	21.06
15	318	97	4914	393	114	6215	26.48
16	323	96	5136	390	109	6236	21.42
17	326	91	5071	405	117	6290	24.04
18	329	95	5115	410	106	6175	20.72
19	321	92	5090	388	111	6186	21.53
20	330	93	5120	376	108	6185	20.80
21	325	97	5122	370	115	6295	22.90
22	316	94	5116	369	110	6275	22.65

23	324	92	5052	381	108	6290	24.51
24	328	90	5118	393	112	6270	22.51
25	321	96	5075	382	114	6102	20.24
Avg.	323	93	5138	388	110	6211	20.94

From Table-1, it is clear that, in conventional practice the average no. of panicles per meter square was only 323 whereas it was 388 in demonstration plot, similarly the average grain yield was 5138 kg/ha and 6211 kg/ha in conventional and demonstration plots respectively (Fig. 1).

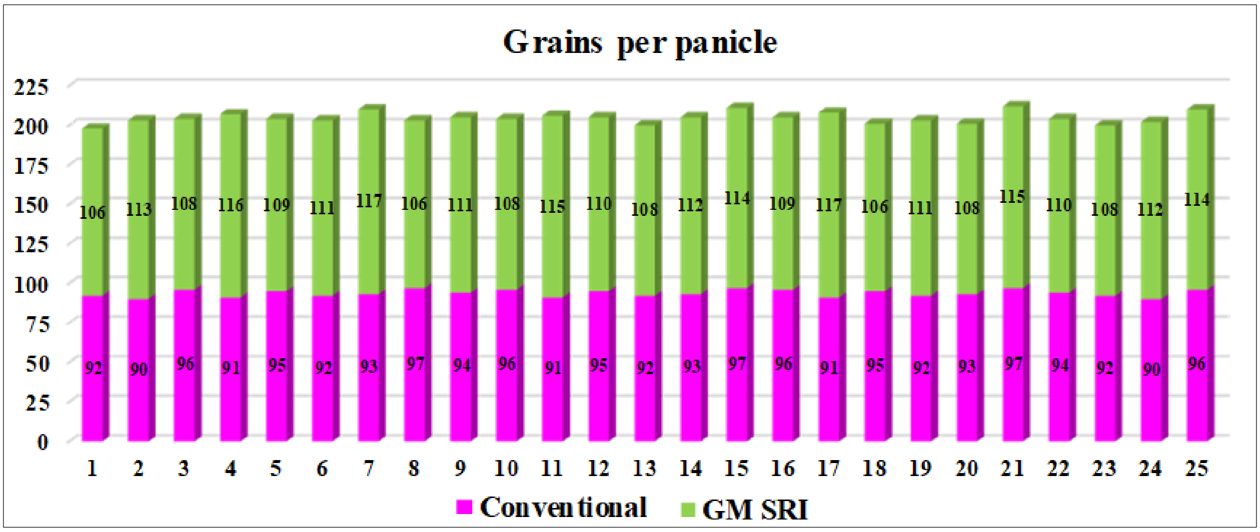

Fig 2: Grains per panicle in conventional and GM-SRI plots

According to Gopalakrishnan, *et al.* [7]. 2014, the SRI practices create favourable conditions for beneficial soil microbes to prosper, save irrigation water, and increase grain yield. Hence the findings are in line with the earlier studies. The possible reason for such result may be due to adoption of recommended intercultural operation like split dose of fertilizers and use of biofertilizers other than in-situ mulching with green manure before transplanting main crop. The average yield increase of 20.94% was observed.

Green Manure Accumulation

Green manure is a specific species of plant, usually a legume, which are planted prior to main crop and puddled into soil for enhancing soil health (Fig. 3). Green manuring is the process of incorporating green plants into the soil either by raising in same field or plants grown elsewhere at the green stage before flowering. Sesbania Rostrata was suggested as potential green manure, which has capacity to produce both root and stem nodules and can grow in flooded as well as dory conditions (Dreyfus *et al.*, 1984) [4]. Studies conducted on nodulation of *S. rostrata* showed that due to profuse stem nodulation, besides root nodulation, it has five to ten times more nodules· than most root nodulated green manure species (Dreyfus and Dommergues, 1981) [16]. Green manure amendments stimulate soil microbial growth, enzymatic activity, microbial biomass carbon and nitrogen with subsequent mineralization of plant nutrients. Application of high-quality green manure such as legumes with low lignin and low C/N ratio could provide nutrient more efficiently by releasing nutrient quickly to plant. Sesbania ranks first among green manures in contributing biomass and nitrogen to the fields (Dubey *et al.*, 2015) [5]. In the present study, the quantity of drymatter produced were recorded beneficiary wise. The details of drymatter production and corresponding addition of nitrogen to the soil are tabulates in Table-2 below.

Fig 3: Incorporation of green manure

Table 2: Dry matter production and Quantity of Nitrogen Added to the Soil

S. No.	GM-SRI Plot No.	Dry matter (t/ha)	Nitrogen Added (Kg/ha)
1	1	2.6	50
2	2	2.4	52
3	3	2.1	51
4	4	2.2	48
5	5	2.6	52
6	6	2.3	49
7	7	2.5	50
8	8	2.2	52
9	9	2.3	51
10	10	2.1	50
11	11	2.4	52
12	12	2.3	49
13	13	2.2	51
14	14	2.6	48
15	15	2.1	52
16	16	2.6	50
17	17	2.4	52
18	18	2.5	51
19	19	2.2	48
20	20	2.4	52
21	21	2.1	49
22	22	2.2	50
23	23	2.6	52
24	24	2.3	51
25	25	2.5	50
Average		2.34	50.48

The importance of GMs in the improvement of soil CEC has been demonstrated by many researchers (Kimetu *et al.*, 2008; Saria *et al.*, 2018) [8]. Therefore, it may be concluded that GMs protect cation from leaching out of the plant root zone and makes them available to plant roots. Thus, Green manure application to agriculture soil has been proven for increasing nutrient retention, nutrient-uptake efficiency, soil organic matter, microbial biomass, nutrient-uptake efficiency and reducing soil erosion nutrient. GM such as *S. rostrata* accumulate large amounts of sulphur, boron, manganese, molybdenum and zinc from rich subsoil (Rayns and Rosenfeld 2010) [12]. From the observation it is evident that the average drymatter production in one hectare of demonstration plot was around 2.34 t/ha and the average nitrogen fixed in the soil was found to be 50.48 kg/ha. The result is in line with the earlier studies.

Economics of GM-SRI Intervention: The agriculture of the modern chemical era concentrates on maximum output but overlooks input efficiency as a result of which it has not been sustainable. Green manuring of rice is a well-established practice and saving of fertilizer N through green manuring ranged from 30 to 100 kg N ha^{-1}. Combined application of fertilizer and green manure increased the efficiency of each other. Before the intervention, the farmers were able to get only low yield than the potential yield due to improper intercultural practices and non-judicious use of fertilizers resulting in high cost of cultivation and poor yield cum economic returns from the investment made. After the intervention, the farmers practiced the recommended technologies and package of practices in an integrated manner which resulted in expected yield and economic returns. The details of economics worked-out in conventional rice cultivation and the GM followed by SRI is furnished in the Table-3 and Fig.4 as below.

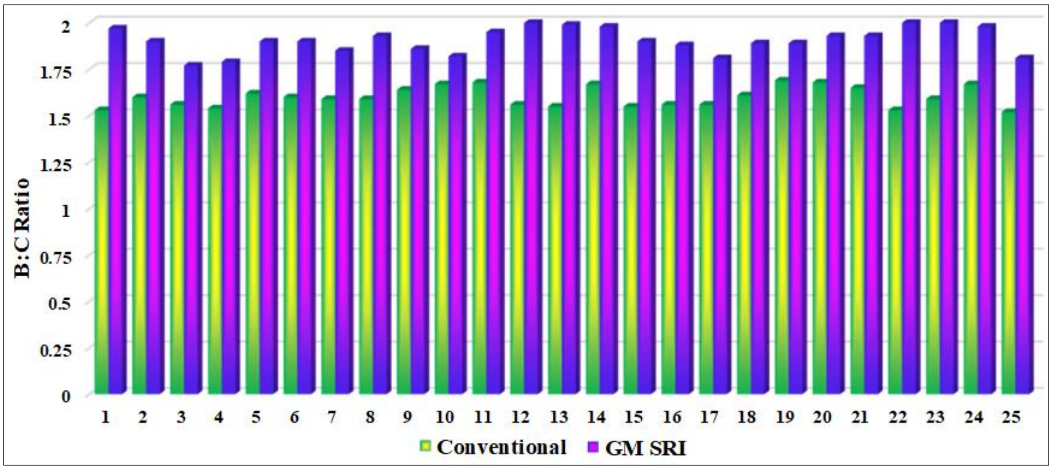

Fig 4: Cost to Benefit Ratio of conventional and GM-SRI

Table 3: Economics of conventional versus GM-SRI

Plot No.	Conventional				GM SRI (Demo)			
	Gross Cost (Rs/ha)	Gross Income (Rs/ha)	Net Income (Rs/ha)	BC Ratio	Gross Cost (Rs/ha)	Gross Income (Rs/ha)	Net Income (Rs/ha)	BC Ratio
1	34450	52780	18330	1.53	36800	72500	35700	1.97
2	34200	54650	20450	1.60	39200	74480	35280	1.90
3	34350	53540	19190	1.56	37500	66540	29040	1.77
4	34005	52460	18455	1.54	38200	68540	30340	1.79
5	34100	55305	21205	1.62	37150	70560	33410	1.90
6	34150	54785	20635	1.60	37890	72156	34266	1.90
7	34300	54625	20325	1.59	38650	71456	32806	1.85
8	34800	55369	20569	1.59	36200	69845	33645	1.93
9	34245	56148	21903	1.64	36805	68564	31759	1.86
10	34605	57854	23249	1.67	37650	68503	30853	1.82
11	34500	58100	23600	1.68	37500	73250	35750	1.95
12	34000	53156	19156	1.56	36950	74300	37350	2.01
13	34508	53460	18952	1.55	36800	73250	36450	1.99
14	34200	56987	22787	1.67	37050	73200	36150	1.98
15	34250	52950	18700	1.55	39055	74050	34995	1.90
16	34300	53654	19354	1.56	39100	73500	34400	1.88
17	34325	53698	19373	1.56	38650	69870	31220	1.81
18	34025	54896	20871	1.61	38256	72350	34094	1.89
19	34450	58239	23789	1.69	38350	72300	33950	1.89
20	34300	57648	23348	1.68	38150	73600	35450	1.93
21	34255	56424	22169	1.65	37986	73230	35244	1.93
22	34290	52348	18058	1.53	36900	74300	37400	2.01
23	34365	54621	20256	1.59	37320	74500	37180	2.00
24	34156	56895	22739	1.67	37560	74258	36698	1.98
25	34350	52125	17775	1.52	39030	70589	31559	1.81
Avg.	34299	54908	20609	1.60	37788	71987	34199	1.90

It has been established that organic matter amendments to soil improves utilization of naturally stocked soil micronutrients, and thereby reduce any need for major external inputs (Aghili *et al*., 2014) [1]. From the Table-3, we can clearly understand that, before the intervention the average net return was only Rs.20,609 per hectare whereas it was Rs.34,199 from conventional and demonstration plots respectively similarly the average cost to benefit ratio was 1.60 in conventional method and later it was notice 1.90 in demo plot.

Conclusion
Green manure can represent the sustainable tools for to improve soil fertility in intensive agriculture. Green manure has multiple effects on crop performance as well as soil management. Understanding the relative importance of green manure and use it as a part of cropping system might be able to applicable for soil rehabilitation and reclamation of land. They also contribute to the yield enhancement in main crop besides improving soil health. Hence, the farmers growing rice in wetland ecosystem are advised to take-up green manure followed by SRI as cropping pattern for sustainable yield and economic returns

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